GRAZING MANAGEMENT EFFECTS ON SURFACE RUNOFF FROM PASTURES FERTILIZED WITH BROILER LITTER

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Abstract. Repeated heavy applications of broadcast broiler litter can increase nutrient runoff from pastures. Rotational stocking of cattle, as compared to continuous stocking, may be useful in decreasing surface nutrient runoff because of better manure distribution and more uniform forage accumulation to act as filters and trap nutrients. The objective of this study was to measure phosphorus runoff from six 0.75-ha (6-8% slope) endophyte-infected tall fescue-common bermudagrass pastures that were fertilized with 13 to 15 Mg (dry weight) ha^{-1} yr^{-1} broiler litter. Runoff was analyzed for dissolved reactive P (DRP) and total Kjeldahl P (TKP). Grazing method had no effect ($P>0.10$) on surface runoff quality or quantity. The average flow weighted concentration of DRP for both stocking treatments was 5.1 mg P L^{-1} for the first year and 8.2 mg P L^{-1} for the second year ($P<0.10$). The flow weighted concentration of TKP was 6.8 mg P L^{-1} for the first year and 12.8 mg P L^{-1} for the second year ($P<0.10$). A substantial portion of the second year nutrient loss came from a single runoff event that occurred just two days after the third broiler litter application.

INTRODUCTION

Tall fescue and common bermudagrass require substantial fertilization to provide beef producers adequate forage for sustainable operations (Huneycutt et al., 1988). Bosch and Napit (1992) concluded that the use of broiler litter as a nutrient source is an economical alternative to commercial fertilizers. Broiler litter is a by-product of broiler production and consists of poultry excreta, feathers, wasted feed, and bedding material.

Mixed pastures of tall fescue-common bermudagrass are used extensively as a nutrient sink in north Georgia's broiler production belt. Due to the large amounts of broiler litter produced and limited suitable land area on which to spread it, broiler litter is frequently applied at high rates. Excessive litter application threatens the health of the environment due to potential pollution of ground water with NO_3^--N and contamination of surface water with dissolved reactive P (DRP) (Liebhart et al., 1979; Edwards and Daniel, 1992).

In pastures fertilized with broiler litter, rotational stocking (RS) may prove to be a means of increased nutrient utilization and decreased nutrient runoff if plant growth and uptake of nutrients are enhanced by intensive management of grass stands. The objectives of this study were to evaluate the effect of stocking method, RS versus continuous stocking (CS), on quantity and quality of surface runoff from tall fescue-common bermudagrass pastures fertilized with broiler litter.

MATERIALS AND METHODS

Six 0.75-ha mixed endophyte-infected tall fescue-common bermudagrass pastures (6-8% slope) provided three replications each of RS and CS to compare stocking method effects on surface runoff quality and quantity. The pastures were located at the Central Georgia Branch Station, near Eatonton, Georgia.

A berm was constructed around each pasture to channel surface runoff to a flume equipped with a sonic sensor to measure depth of flow, and with a Coshocton wheel to subsample surface runoff. During late autumn and early winter 1994-95 all pastures were managed under CS at a moderate rate (target forage available of 1340-1680 kg DM ha^{-1}) to establish baseline values for surface runoff quality and quantity. All surface runoff samples generated during the study were collected and refrigerated (4°C) by a refrigerated sampler. Precipitation and runoff volume data were recorded with dataloggers. Samples were kept refrigerated (4°C) in the laboratory after delivery from the field.

Broiler litter was broadcast annually at 13 to 15 Mg (dry weight) ha^{-1} yr^{-1} in split applications during late winter and early autumn. A target application rate of 300 kg available N ha^{-1} yr^{-1} in two applications was used to determine the broiler litter application rate. Four broiler litter applications were made during the 2 yr of the study (A1, A2, A3, A4), with the actual amounts of nutrients applied varying between applications due to variations in the moisture and nutrient contents of the litter (Table 1). The pastures had not been fertilized with broiler litter prior to initiation of the study.

Each of the three RS pastures were divided into eight paddocks, allowing 3 d of grazing and 21 d of rest in each rotation. Grazing began according to treatments in April 1995 (after the first broiler litter application) and continued for 2 yr. Stocking rate of beef steers was based on a moderate grazing pressure (target forage available of 1340 to 1680 kg DM ha^{-1}). A put and take system of steer management was used to maintain a similar grazing pressure between stocking methods. The forage available in CS pastures dictated the minimum number of steers per pasture. Additional steers in excess of those added to CS pastures were added to RS pastures as available forage allowed.

Prior to initiating the study and before each late winter application of broiler litter, 12 soil samples were taken to a depth of 15 cm from each pasture. In October, 1995, prior to the second broiler litter application, 12 soil samples were taken to a depth of 5 cm from each pasture. While each soil sample was analyzed independently for Mehlich I P (Mehlich, 1953), the resulting values were averaged by pasture and sampling period.

Surface runoff samples were analyzed for DRP and TKP. Dissolved reactive P was determined on filtered (0.45 μm) surface runoff samples. TKP was determined on unfiltered surface runoff samples. Flow weighted concentration of nutrients (mg L^{-1}) in the runoff were calculated by dividing the mass of nutrient lost during a given period by the corresponding total amount of runoff recorded. Average annual runoff was expressed as a percentage of the total precipitation received for the year. Broiler litter samples were analyzed for TKN and TKP to determine nutrient content.

Table 1. Nutrients applied in broiler litter

Date	Litter	Total N	Total P
	--------kg ha^{-1} (dry weight)--------		
A1 3/16/95	5929	267	102
A2 10/30/95	6771	267	112
A3 3/4/96	8258	502	174
A4 9/25/96	6408	260	103

Baseline nutrient concentration and runoff quantity were analyzed using PROC GLM of PCSAS (SAS Institute, 1990) using a completely randomized design (CRD) to determine differences in pasture response prior to assigning treatments. Grazing method effects on nutrient concentration of runoff, runoff quantity and extractable soil P were analyzed using PROC GLM of PCSAS (SAS Institute, 1990) using a CRD. Based on significance by year of the study, the data were sorted by year and an analysis was conducted to evaluate the effect of grazing method on nutrient concentration and runoff percent.

RESULTS AND DISCUSSION

Analysis of the baseline runoff quality and quantity data revealed no differences ($P>0.10$) between pastures prior to assignment of grazing method and application of broiler litter. The total rainfall for the baseline period was 184 mm. The mean flow-weighted DRP concentration of the baseline runoff was 0.4 mg P L^{-1}, a concentration in excess of the US EPA guidelines for lakes and streams. Average TKP was 1.4 mg P L^{-1}. Mean runoff was 25 mm, which corresponds to 13.7% of the total precipitation received. Lack of substantial sediment in the baseline runoff removed this variable from consideration in the study.

Grazing method had no effect ($P>0.10$) on quality or quantity of surface runoff. Precipitation amounts of 1158 and 1094 mm were recorded for the first (Y1) and second (Y2) treatment years, respectively. The annual rainfall amounts were consistent with 30-yr average annual precipitation of 1135 mm recorded for Macon, GA , the official weather station in closest proximity to the study.

Average flow-weighted DRP and TKP concentrations were different ($P<0.10$) in a comparison of Y1 and Y2 (Table 2). The first large runoff event following A1 and A4 occurred 202 and 171 days after application, respectively, (Fig. 1). The lapse in time between litter application and surface runoff for A1 and A4 was sufficient for appreciable nutrient transformation to occur. In contrast, the first large runoff event following A2 and A3 occurred 11 and 2 d after application, respectively, (Fig. 1). Due to the shorter time interval between application and runoff-producing precipitation, especially for A3, relatively reduced transformations, other losses, or movement of the nutrients would have occurred. Dissolved reactive P and TKP reached high values of 9.6 and 22.5 mg P L^{-1}, respectively, in the runoff event following A3.

The phosphorus concentrations for the runoff event occurring two days after A3 are contained in the flow-weighted values for Y2 and account in part for the increased ($P<0.10$) concentration compared to Y1. The target broiler litter application rate was exceeded for A3 due to higher than expected nutrient concentration and a change in application operators (Table 1). In addition to these factors, the effect of repeated broiler litter applications on P accumulation in the surface horizon is likely responsible for elevated concentrations of P in Y2. Extractable soil P in the upper 15 cm increased ($P<0.10$) from 12 to 81 mg Mehlich I P kg^{-1} over the 2 yr period. Grazing method had no effect ($P>0.10$) on extractable soil P in the upper 15 cm.

Dissolved reactive P concentration in surface runoff was highest in the runoff events occurring soon after broiler litter application compared to the events that occurred at least 170+ days after application. However, when comparing DRP concentration in the baseline runoff with the runoff following A1, it is clear that a single broiler litter application caused a large increase in the runoff concentration of DRP (Fig. 1). Dissolved reactive P was consistently in excess of the US EPA guidelines for streams (0.10 mg P L^{-1}) for all samples collected in the four 'first' runoff events following broiler litter application.

Table 2. Average flow-weighted P concentration (mg L^{-1}) and runoff (as % of rainfall)

Item	Year 1	Year 2	LSD (0.10)
DRP	5.1	8.2	2.2
TKP	6.8	12.8	3.7
Runoff	14.6	11.6	1.6

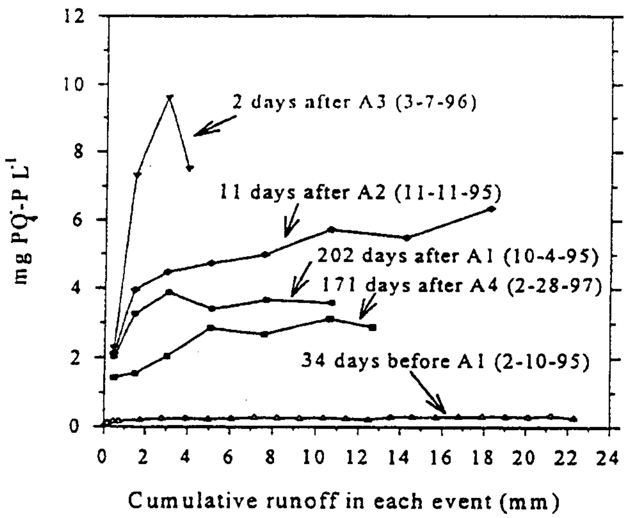

Fig. 1. Concentration of dissolved reactive P in runoff from tall fescue-bermudagrass pasture (watershed 1, continuously stocked) during 1995 - 1997.

Ranging from 75 to 200 mg P kg^{-1} soil and specified by P extraction method, several states have established critical soil test P values for making nutrient management recommendations even though limited data are available to theoretically justify them (Sharpley et al., 1996). While soil test P concentration (mg kg^{-1}) of surface soil is related to the concentration of DRP in runoff, Sharpley et al. (1996) concluded that soil test P should not be the sole criteria to determine the potential for P enrichment of runoff and subsequent fertilizer or manure application rates, particularly without an estimate of runoff or erosion potential.

Results from Pote et al. (1996) for tall fescue plots in Arkansas suggested that approximately 200 mg kg^{-1} Mehlich 3 P (resulting from application of inorganic fertilizer, or swine or poultry manure at least one year prior to simulated rainfall) in the surface 2 cm of soil would produce a DRP concentration of 1 mg L^{-1}. In this study, we measured concentrations of 3 to 5 mg DRP L^{-1} in the runoff that occurred 202 d after A1. Soil samples (0-5 cm) collected 12 days after that runoff event resulted in Mehlich I P concentrations of 28 to 61 mg P kg^{-1}. Given that the soil test values were relatively low, these figures suggest that the main factor controlling DRP in the runoff was not soil test P, but instead broiler litter P on the soil surface.

On average, 68% of the TKP in the surface runoff was DRP. This is consistent with previously reported data (R.W. Vervoort et al., 1998). Consequently, filter strips, a practice to trap sediment and related sorbed P, will likely not be useful in reducing P levels in surface runoff from pastures repeatedly fertilized with broadcast broiler litter.

SUMMARY AND CONCLUSIONS

Dissolved reactive P, linked to eutrophication, increased from an average 0.4 mg P L^{-1} during the baseline period to an average 8.2 mg P L^{-1} during Y2. Total Kjeldahl P increased from an average 1.4 mg P L^{-1} during the baseline period to an average 12.8 mg P L^{-1} during Y2. Considering relatively low initial soil test P values and the length of time between broiler litter application and the first runoff event, flow weighted DRP was exceptionally high in the first runoff event following A1. This suggests that P in broiler litter broadcast applied to the soil surface was a controlling factor for DRP concentrations in runoff. While the P concentrations were high in comparison to the US EPA guidelines for P in lakes and streams, the significance of P in edge-of-field runoff is related to how much dilution takes place from the edge of the field to the point where the runoff enters a lake or stream.

The data from the runoff following A3 emphasizes the importance of timing of broiler litter application with respect to the first runoff-producing rainfall event. Most of the large runoff events occurred on saturated soils in winter and early spring. It is therefore important to delay broiler litter application during this time when a large probability of runoff-producing rainfall can be expected. Considering the water quality or quantity parameters measured in this study, RS was not superior to CS in tall fescue-bermudagrass pastures fertilized with broiler litter.

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